ACCEPTED PAPERS/ABSTRACTS

Alexandru Baltag and **Sonja Smets**
LOGICS FOR REASONING ABOUT QUANTUM INFORMATION: A DYNAMIC-EPISTEMIC PERSPECTIVE

In this talk we show how ideas coming from two areas of research in logic can reinforce each other. The first such line of inquiry concerns the "dynamic turn" in logic and especially the formalisms inspired by Propositional Dynamic Logic (PDL); while the second line concerns research into the logical foundations of Quantum Physics, and in particular the area known as Operational Quantum Logic, as developed by J.M. Jauch and C. Piron in the late sixties and seventies. By bringing these areas together we explain the basic ingredients of Dynamic Quantum Logic (DQL), a new direction of research in the logical foundations of physics. Besides the standard quantum properties such as non-locality and entanglement we will look at extensions that allow us to reason about both classical and quantum information flow. We pay special attention to specific features that refer to the epistemic effects and the ontic effects resulting from performing observations or measurements on a quantum system, as well as to the agent's local "control" (i.e. the fact that classical agents may have only access to a part of a quantum system). Time permitting, we will illustrate how to model these specific features in our logical setting by using specific quantum information protocols as examples.

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S. Barry Cooper
TYPECASTING NON-LOCALITY

As philosopher Tim Maudlin describes (p.4 of "Quantum Non-Locality and Relativity", 2011 edition):
"For those interested in the fundamental structure of the physical world, the experimental verification of violations of Bell's inequality constitutes the most significant event of the past half-century."

In this presentation we spotlight both familiar and other less well-known examples of non-locality in mathematics, evoking informational typing and its corresponding computational and definability theoretic infrastructure. The aim is the achievement of a widely applicable framework out of which infinitary computation and nonlinear causality emerge very naturally, providing a receptive host for non-locality across a spectrum of contexts.

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Mark Hogarth
NEWCOMB'S PARADOX AND SPACETIME

I investigate relativistic spacetimes that can accommodate the story behind Newcomb's paradox. Two kinds of spacetimes are germane: spacetimes that allow time-travel into the past (e.g. the Gödel universe) and so-called 'predicable spacetimes' (spacetimes that admit a Cauchy surface to the past of an event). I will argue that in the context of these arenas, the air of paradox vanishes.

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Thomas Müller
WHAT IS A POSSIBLE CASE IN BRANCHING SPACE-TIMES?

The title of this talk highlights a question to which we have, as of yet, no firm answer. I want to show how the question arises, why it is important, and where an answer might lie.

Branching space-times (BST), due to Belnap (Synthese 92 (1992), 385--434), is a theory that combines, in a logically rigorous fashion, elements of relativity theory with indeterminism. A model of BST comprises several possible histories, each of which is a single space-time. Intricacies of BST concern the way in which these space-times are put together in one model; these intricacies are connected with questions of topology and of space-like correlations. In recent years, there have been several studies developing these issues.

It should be possible to use BST models as the basis for a modal logic of space-time. There have been a few attempts at such a development, but no larger systematic studies. It should be helpful to develop such a logic in analogy with extant temporal-modal logics. Such logics often use models with branching histories as well, but in extant systems these histories are linearly ordered and do not represent spatial extension.

For any modal logic, a crucial question is the question of the parameters of truth. With respect to what does one assess a sentence as true or as false? Such a set of parameters specifies what we call a possible case. In standard modal logic, truth is relative to a possible world: a case is a world. A temporal-modal logic is more fine-grained than that, and it is appropriate to take truth to be relative to both a moment in time and a possible history (so-called Ockhamism; see Belnap and Müller, J Phil Logic 43 (2014), 835--866): a case is a moment-history pair. My title question is what truth should be relative to in BST: What is a possible case in BST? There are several options. The talk will describe these options and asses their pros and cons.

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István Rácz
THE MANY FACES OF THE CONSTRAINTS IN GENERAL RELATIVITY

In this talk the constraint equations for [n+1]-dimensional (with n> 3) smooth Riemannian and Lorentzian spaces satisfying Einstein's equations will be considered. Under some mild topological assumptions it is shown first that whenever the primary space is Riemannian the 'Hamiltonian' and 'momentum' type expressions satisfy exactly the same type of first order symmetric hyperbolic subsidiary system as they do in the conventional Lorentzian case. It is shown then that, regardless

whether the primary space is Riemannian or Lorentzian, the constraints can always be put into the form of an evolutionary system comprised either by a first order symmetric hyperbolic system and a parabolic equation or, alternatively, by a strongly hyperbolic system subsided by an algebraic relation. The (local) existence and uniqueness of solutions to these evolutionary systems is also shown verifying thereby that the proposed evolutionary approach provides a viable alternative to the apparently unique conformal method.

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Valentin B. Shehtman
SQUARES OF MODAL LOGICS AND RELATION ALGEBRAS

Study of relation algebras is one of the most intriguing parts of algebraic logic applying problems and methods from different fields - classical logic, algebra, games, geometry. Since the end of 20th century it has essentially involved modal logic. In this talk we concentrate on a special type of two-dimensional modal logics, so-called Segerberg squares. Segerberg squares can be interpreted as special fragments of equational theories of (representable) relation algebras; in many cases they are finitely axiomatizable, and in some cases decidable. We also specify locally finite Segerberg squares and show how bisimulation games can be used to prove the local finiteness.

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László E. Szabó
MEANING, TRUTH, AND THE DIFFEOMORPHISM INVARIANCE

I will start with three philosophical premises: (1) Physicalism -- everything is physical; all facts supervene on, or are necessitated by, the physical facts. (2) Empiricism -- genuine information about the world can be acquired only by a posteriori means. (3) Formalism -- logic and mathematics are thought of as statements about manipulations with meaningless symbols. Then, I will outline the basic ideas of the so-called physico-formalist philosophy of mathematics, an account of logic and mathematics that is completely compatible with these philosophical doctrines. In the same spirit, combining the physico-formalist approach to formal system with an intuition we can learn from Gödel's proof of incompleteness theorem, we develop a physicalist--formalist--empiricist theory of meaning and truth with respect to physical theories. Finally, in the light of these considerations, I will discuss the problem of diffeomorphism invariance in general relativity.

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Hajnal Andréka and **István Németi**
VARIETIES OF CONCEPT ALGEBRAS [**pdf**]

Concept algebras are central tools in connecting, combining and comparing theories. They are useful in investigating relativity theory as a network of logic theories. Concept algebras of first-order logic were named cylindric algebras by Alfred Tarski, because of the geometrical meaning of the quantifiers. When we use N many variables, the concepts are subsets of an N-dimensional Cartesian space, and we talk about N-dimensional cylindric algebras. Concept algebras synthesize logic, algebra and geometry.
We prove that there are 2 to the N many equational theories of

the representable N-dimensional cylindric algebras, solving Problem 4.2 in the Henkin-Monk-Tarski 1985 monograph on cylindric algebras. The proof hinges over the existence of non-symmetric representable cylindric algebras. By showing that each endo-dc algebra is symmetric, this solves Problem 2.13 from the Henkin-Monk-Tarski 1971 monograph. We introduce the so-called lifting varieties and we prove that the varieties generated by locally finite-dimensional cylindric algebras are exactly the lifting varieties. Lifting algebras are all symmetric. All this has logical consequences for the formula-schemes valid in first-order logic, for type-free logic, and for the finitary logic of infinitary relations.

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Thomas Barrett and **Hans Halvorson**
GLYMOUR AND QUINE ON THEORETICAL EQUIVALENCE [**pdf**]

Logicians and philosophers of science have long been concerned with the conditions under which theories might be considered equivalent. One way that this issue has been approached is by proposing different formal criteria for theoretical equivalence. In this paper we discuss two such criteria. The first was proposed by Glymour (1970, 1977, 1980) and the second was proposed by Quine (1975).

We begin by showing that Quine's criterion is unsatisfactory. It considers some theories to be equivalent that one has good reason to consider inequivalent. But Quine's criterion can be amended in such a way that it no longer makes these undesirable verdicts. Indeed, we will isolate a precise sense in which Glymour's criterion is such an amendment.

In our talk we will also discuss another criterion for theoretical equivalence: Categorical equivalence. Halvorson (2012, 2015) and Weatherall (2015) have recently introduced this criterion into philosophy of science. We will show here how it is related to other extant criteria for theoretical equivalence.

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Neil Barton
MODALITY, MATHEMATICS, AND TIME; A COMMON FLAW IN MODAL ARGUMENTS. [**pdf**]

Modality in the context of mathematical discourse has received increased attention recently. In this paper I analyse a kind of modal argument that can be brought against the position that there is a single, determinate, maximal interpretation of set-theoretic discourse. I argue that attempts to deepen Naturalistic problems through modal considerations are closely analogous to Gödel's argument from General Relativity Theory against the reality of Time. Both I argue fall flat against their targets for similar reasons; an imprecision in the modality used in the arguments results in principles that appear true, but are unlikely to be jointly accepted with the same modality in play by the parties in question. I conclude with some observations concerning the kinds of possibility at issue, and argue that the problems posed by forcing extensions and proper classes are not deepened by modal considerations.

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Thomas Benda
HOW AN AXIOMATIC BOHMIAN FIELD THEORY COULD LOOK [**pdf**]

A first-order axiomatic theory SB is set up that is a stepping stone to the construction of a relativistic dynamics in the spirit of Bohmian mechanics. SB extends a theory ST which constructs relativistic spacetime from worldlines as primitive objects. In SB, every worldline v is furnished with a wave function, which is obtained by the relation of v intersecting with other worldlines. At the present stage, the wave function of a given worldline is not specified, but only introduced as a formal entity. By the Bohmian dynamic equation, at each spacetime point a four-velocity is calculated, from which a stress-energy tensor is obtained. Thus the theory SB provides an axiomatic framework for a physical theory which is relativistically covariant and reduces in the limit case of small non-interacting particles to Bohmian mechanics.

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Dániel Berényi and **Gábor Lehel**
THE BRIDGE BETWEEN MATHEMATICAL MODELS OF PHYSICS AND GENERIC SIMULATIONS [**pdf**]

We would like to draw attention to the fact that abstractions related to logic and mathematical models of physics soon going to be necessary to the development of generic high-performance simulations to advance computational physics. The common language to describe and formulate these is already available in some high-level languages and the main cornerstones are rooting in category theory that in turn again related to the basic foundations of mathematics and physics. The types that many people thought are just used for differentiating integers from floating point numbers in computer programs have grown not just to give the main structure of modern computer programs but recent research is focused on founding mathematics and physics on them.

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Kevin Coffey
MASS AND ENERGY IN SPECIAL RELATIVISTIC DYNAMICS [**pdf**]

This paper considers the special relativistic relationship between mass and energy as embodied in Einstein's famous equation $E=mc^2$. I argue that the most natural candidates for understanding this relationship are inadequate, and thus that important conceptual and philosophical work on the dynamics of special relativity remains to be done. This paper forms part of a larger project concerning the interpretation and ontology of special relativity.

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Diana Constantin and **Erika Varga-Verebélyi**
GRAVITATIONAL REDSHIFT AND THE SINGULARITY EFFECT IN THE FRAME OF THE POST-NEWTONIAN DE SITTER FIELD

We analyze the gravitational redshift in the two-body problem in the post-Newtonian de Sitter-type gravitational field. Considering the associated potential to compute the gravitational redshift, we

start from the conservation of energy law in the special relativity approximation (SRA) and from the general relativistic metric in the general relativity approximation (GRA). In both of cases, the gravitational redshift computed values are similar. We obtain as a necessary condition that the cosmological contant Λ to be less 0 to compute the gravitational redshift. In addition, in the GRA frame, we identify a "black hole effect" which consists of a positive real value for the gravitational radius (denoted ρd'S) of Cauchy's horizon. Furthermore, we compare ρd'S with both the gravitational radius of Maneff' scaled field (denoted RM) and the radius which occurs in the Schwarzschild problem (denoted ρS).

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Newton C. A. Da Costa and **Francisco Antonio Doria**
ON SET--THEORETICALLY GENERIC SPACETIMES

We present an axiomatization for general relativity with the help of Suppes predicates, and consider its behavior when we change the underlying set--theoretic model by forcing techniques.

We discuss the following questions:

- Are there set--theoretically generic spacetimes which are physically different from standard (or perhaps constructive) spacetimes?
- Are there set--theoretically generic spacetimes with a global time coordinate? (Are there generic Big Bang models?)
- Which is the meaning of set--theoretically generic and exotic spacetimes?
- Can we prove density theorems about these objects?

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György Darvas
HOW MUCH RELATIVISTIC WAS "CLASSICAL" QED?

"Classical" QED (1928-1932) aimed at describing the quantum theory of the electron. There were two approaches. One of them started from a picture in which it supposed that there are the (static, scalar) Coulomb potentials of the electric charges what initially interact, and took into consideration the interaction between their vector potentials as perturbation. So did Dirac, Fermi and Breit in accordance with the Heisenberg-Pauli formalism. The opposite approach considered a kinetic interaction in the unperturbed Hamiltonian, and took into account the Coulomb interaction in the perturbation. The models by Møller and Bethe-Fermi belonged to the latter approach. All the mentioned models considered the roles of the interacting electrically charged particles equivalent. In 1932, Bethe proposed Fermi to prove the equivalence of the model presented by Møller and the former Dirac-Fermi-Breit type descriptions of the interaction between two electrons. Both pictures were approximations, and both led to relatively good results in accordance with the experience.

These models were relativistic in the sense that they were invariant under Lorentz transformation. Nevertheless, according to our confidence in the relativity theories, the demand of invariance under Lorentz transformation is a necessary condition for all physical theories. No one questions its validity. Less word is devoted to the question, whether is this also a sufficient condition.

No physical principle states it is sufficient in all cases, although in many situations it is. With caution, we can demand only that physical theories must be invariant under certain transformations, which include Lorentz transformation. What others may they include?

Dirac's 1928 model -- the s.c. Dirac equation -- is still a standard item in most textbooks. However, Dirac itself considered his original paper only an approximation, and he made -- among others -- two considerable attempts (1951, 1962) to renew the "theory of the electron" as he called it, (and there have been many other attempts after him). This meant that his original theory was Lorentz invariant, but not fully relativistic at higher velocities (energies).

Møller's model started from the scattering matrix of two interacting electrons. His matrix elements included an asymmetric component relative to the roles of the two agents. It could describe -- in principle -- the interaction at higher energies, but Møller could not handle the asymmetry. Then, Bethe proposed to symmetrize those matrix elements artificially to retain the equivalent roles of the two interacting electrons. Unfortunately, due to the later high authority of both Fermi and Bethe this artificial involvement in the theory was not discussed until the early 2000s.

I argue for the correctness of Møller's asymmetric model, for asymmetric roles of interacting fermions, and for an intermediate model between the two above approaches. The latter should be a kinetic model. Møller foresaw (or intuitively felt) that two interacting particles could be in two different states, although he could not clearly identify the essence of the distinction between the roles of the interacting agents. In my opinion, we do not need to demand that the individual interaction potentials be symmetric in respect to the two interacting agents. We need to demand only, that in an opposite situation -- that means, when the second particle plays the active role and the former is the passive (this asymmetry can be exemplified by the emission and absorption of a photon) -- similar (symmetric) potentials hold and their numeric values coincide with those in the first situation. This intermediate model can be interpreted so that at an initial state the Coulomb potential of a particle interacts with the vector potential of another. In another possible interpretation the potential (scalar) part of a Hamiltonian interacts with a kinetic (vector) part.

I show that this approach leads to a really relativistic model of the interaction between fermions, and demonstrate the logic and algebra of an additional invariance that extends the Lorentz transformation at strongly relativistic conditions.

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Ronny Desmet

OUT OF SEASON: THE NEGLECT OF WHITEHEAD'S ALTERNATIVE THEORY OF GRAVITATION AS DUE TO AESTHETIC INDUCTION BY EINSTEIN'S GENERAL THEORY OF RELATIVITY [**pdf**]

From the 1920s to at least the 1970s experimental technology only allowed testing the predictions that Albert Einstein's 1915 general theory of relativity (GTR) and Alfred North Whitehead's 1920-1922 alternative theory of gravitation (ATG) have in common. Consequently, from an empirical point of view, and for at least half a century, the two theories were equally attractive. However, despite the shared empirical adequacy, even the physicists in Whitehead's homeland nurtured Einstein's brainchild and neglected Whitehead's. Clearly, empirical criteria of theory evaluation alone are insufficient to understand why the British physics community, as from the 1920s, favored Einstein's theory above Whitehead's.

In this paper, I argue that students of Whitehead can remedy their lack of understanding of the bad reception of Whitehead's ATG by

taking into account, first, aesthetic next to empirical evaluation criteria and, second, James W. McAllister's theory of aesthetic induction. More importantly, looked at it from a philosophy of science angle, the story of the British evaluation of Whitehead's ATG in the 1920s can be conceived as a historical case study that supports McAllister's theory.

In his 1996 book, Beauty and Revolution in Science, McAllister holds that, when a scientific community evaluates a new theory, the degree of favor attributed to an aesthetic property of this theory is proportional to the degree of empirical success of established theories exhibiting this property. McAllister writes:

"The degree of favor with which scientists have regarded an aesthetic property appears to have responded to the empirical performance of theories that possess that property. If a theory possessing an aesthetic property P scores notable empirical success, the community comes to regard P with increased favor and to expect future theories showing P to be successful too. On the other hand, if there later arise theories that lack P but are empirically more successful than the P-bearing theories, then the community's preference for future theories to show P wanes." (78)

Applying McAllister's theory of aesthetic induction to the case of Whitehead's ATG leads to the following story. In 1919 Einstein's GTR scored notable empirical success, and the British physics community came to regard its aesthetic properties with increased favor. So when in 1922 Whitehead published the most detailed account of his ATG, and its aesthetic properties were observed to be quite different from those of Einstein's theory, British physicists did not favor Whitehead's theory: they did not perceive it as beautiful, and did not expect it to be successful.

Indeed, in the excitement of its sensational verification by Arthur S. Eddington in 1919, the British physics community attributed the very highest degree of empirical success to Einstein's 1915 GTR, hence establishing it as the most important cause of aesthetic induction in post-war physics. So when in the early 1920s Whitehead presented his ATG, and its aesthetic properties (its simplicity, intelligibility, metaphysical allegiance, etc.) were evaluated in comparison with the corresponding properties of Einstein's GTR, British physicists gave them low degrees of aesthetic value â□□ Whitehead's ATG was conceived as less inevitable, less comprehensive, less parsimonious, etc. "It had come out of season" â□□ these are the words Whitehead's biographer used to explain its lack of success. Here is the full quote:

"Whitehead's theory did not fare well with physicists. Eddington, who had done much to get Einstein's work accepted, remarked in 1933 that he could now see that in some respects the philosopher's insight had been superior, but that it had come out of season for the physicist." (Lowe 1990:127)

In this paper, after giving a more detailed account of Whitehead's ATG, and of how badly it was received in the 1920s, even by the many high level mathematicians, physicists, and philosophers among Whitehead's friends, I try to put myself in the shoes of an

average British physicist in the 1920s, who has to evaluate Whitehead's theory according to the empirical and aesthetic criteria that McAllister lists in his 1996 book. While performing this evaluation, I will reach three important conclusions: Whitehead's ATG was experimentally indistinguishable from Einstein's GTR in the 1920s (and beyond); its aesthetic properties, however, were seen to diverge significantly from those of Einstein's theory; and the aesthetic induction caused by Einstein's empirically successful GTR has pushed Whitehead's ATG behind the scenes of the theatre of 20th century physics, where it was left for 21st century philosophers to rediscover.

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Juliusz Doboszewski

SPACE INVADERS AND (SMALL) EXOTIC SOURCES [**pdf**]

We discuss similarities between the space invaders scenario in Newtonian mechanics and spacetimes obtained using small exotic smooth structures on the topological manifold R4 in classical general relativity.

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Samuel Fletcher

DEFINITIONS AND CONTEXTUALISM FOR TOPOLOGIES ON THE SPACE OF SPACETIMES [**pdf**]

There is an intuitive idea that some spacetime models are similar to others in some relevant respect or other. A natural way to make this notion precise that one find in the literature is to put a topology on the space of spacetimes which respects the aspects that one wishes to capture.
This article has two purposes. The first is to show that various definitions of certain of these topologies are in fact equivalent. The second is to prove some generalization of propositions of Fletcher, which support methodological contextualism with regard to the topology on the space of spacetimes. This is the position that there is no canonical such topology, and that the different choices thereof that one can make for particular problems should be determined by the context of that problem.

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Michele Friend

A PLURALIST MATHEMATICAL PRACTICE [**pdf**]

"The Andréka-Németi Project" is the honorary name given to a programme to give the logical foundations of theories of physics. The methodology is pluralist. The group carrying out the programme claim to have a better understanding of the physical theories than they would have done had they studied the theories in the standard way: from the laws of physics as they are given to us in physics classrooms and textbooks.

In this presentation I outline some of the methodology, point out in what sense it is pluralist, and in what ways it could become more pluralist. I also discuss the epistemological advantages and disadvantages of the methodology.

The methodology starts with the observed data of the physical theory. This stays fixed, since it is this that the members of the group want to understand. They then develop a logical language that can be used to describe the data, work 'backwards' to find out what axioms could be used to derive the data as theorems. They also derive some of the textbook 'laws of physics' as theorems. Of course, the direction is back-and-forth. The goal is to find the logically simplest and more logically intuitive axioms. But they do not stop once they have found some logical axioms powerful enough to derive all the data. The axioms are not new laws of physics!

Instead, they then explore what happens if they change the axioms, by simplifying them or weakening them. So, they end up with a number of axiomatic systems each of which derives all or some of the data as theorems of the formal system. So we have a plurality of formal axiomatic systems that together give the explanation of the physical data, or so the members of the Andréka-Németi group claim. The methodology is pluralist in: formal axiomatic systems, in ontology and in logic. Each of these terms will be explained. Suggestions will also be made as to how they could be even more pluralist without loosing sight of the greater goal of understanding the physical theories.

The methodology is not for everyone. It requires logical sophistication, and is best suited to those who understand through logic, not through intuitions of physical reality. As a method for understanding science, the advantages come from asking logician's questions about the theory and data.

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Márton Gömöri

FACTS AND CONVENTIONS ON POINCARÉ'S DISC

Geometric conventionalism is the thesis that we are free to choose the geometry we use to describe the world. Trivial semantic conventionalism is the thesis that we are free to choose the meanings of the terms in which we describe the world. Empiricists, among them famously Eddington and Reichenbach, argued that the former reduces to the latter: the conventionality of geometry simply consists in the conventional choice of the empirical meanings of geometric terms. We present a case study for this idea. Operational definitions of geometric terms corresponding to the different choices of geometry in Poincaré's disc parable will be given. It turns out that to specify these definitions in a precise, non-circular manner is not as obvious as one might think; and it leads to interesting philosophical observations concerning the subtle interplay of facts and conventions in the epistemology of geometry.

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Bruno Hartmann

OPERATIONALIZATION OF RELATIVISTIC ENERGY, MOMENTUM

AND INERTIAL MASS

This novel approach to the foundation of the physical theory begins with thought experiments on measurement practice like Einstein for relativistic Kinematics. For a similar foundation of Dynamics one can start from Hermann von Helmholtz analysis of basic measurements. We define energy, momentum and mass from elemental ordering relations for ''capability to execute work'' and ''impact'' in a collision and apply Helmholtz program for quantification. From simple pre-theoretic (principle of inertia, impossibility of Perpetuum Mobile, relativity principle) and measurement methodical principles we derive all fundamental equations of Mechanics. We explain the mathematical formalism from the operationalization of basic observables.

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Robin Hirsch and **Mark Reynolds**

DECIDABILITY OF TWO DIMENSIONAL MINKOWSKI SPACETIME

Consider a Kripke frame where the reflexive accessibility relation is â□□can send a signal at the speed of light or lessâ□□. Goldblatt showed that the valid modal propositional formulas for such frames were exactly axiomatised by the modal logic S4.2. It makes no difference if we insist on slower than light messages, on how many spatial dimensions there are, nor whether the underlying coordinate system is based on the real numbers (as normal for Minkowski spacetime) or the rational numbers; in each case the logic is the same S4.2.

We consider instead the temporal logic of Minkowski spacetime, where the temporal operator F (at some point now or in the future lightcone) has an inverse temporal operator P. We show, using a new kind of finite model construction, that the logic of 2D (i.e. 1 time dimension, 1 space dimension) Minkowski frames over the reals is decidable, also the logic of the irreflexive restriction of this accessibility relation. We provide temporal formulas to distinguish between 2 and 3 dimensions, and other types of frames. We conjecture that the temporal logic of higher dimensional Minkowski spacetime is undecidable.

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Sándor Jenei

CLASSIFICATION OF ABSORBENT-CONTINUOUS, DENSELY ORDERED AND COMPLETE, GROUP-LIKE FLE-CHAINS [**pdf**]

The main result of the talk is the classification of absorbent-continuous, order-dense and complete, group-like FLe-chains: Every such algebra can be described as the twin rotation of a certain BL-algebra and its de Morgan dual. This theorem largely generalizes the corresponding main theorem of [Jenei, S., Montagna, F.: A classification of certain group-like FLe-chains, Synthese (2014). doi:10.1007/s11229-014-0409-2] and the complexity and length of its proof is significantly reduced, too. Further generalization of this classification result is not possible; if any of the four assumptions, namely order density, completeness, the group-like property, or absorbent-continuity is dropped then there exist algebras with different form than that of our main theorem.

The main goal of the talk is to demonstrate how underlying geometric ideas and arguments result in proving such a theorem.

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Mohamed Khaled and **Tarek Sayed Ahmed**
GUARDED FRAGMENT OF FIRST ORDER LOGIC WITHOUT EQUALITY [**pdf**]

Let $n \in \omega$ be arbitrary. The guarded fragment of first order logic with only n-many variables and without equality ($GF_n^{\neq}$) was first introduced by Andréka, Van Benthem and Németi, who proved that it is decidable. $GF_n^{\neq}$ was considered by some other logicians and it was shown that $GF_n^{\neq}$ has a number of other desirable positive properties. Guarded fragments have applications in various areas of computer science and was more recently shown to be relevant to description logics and to database theory.

Here, we give different proofs for the decidability and most of the other known properties of $GF_n^{\neq}$, such as soundness, completeness, finite model property and all of the positive definability properties like e.g. Craig interpolation and Beth definability. We also lift some of these results to the guarded fragments of first order logic with infinitely many variables (and without equality). Our proofs are purely algebraic, which makes them readable for the mathematicians that are not necessarily logicians. We achieve this aim by considering some class of Boolean algebras with operators, Crs_n^{df}, which is the class corresponding to $GF_n^{\neq}$.

We show that the free Crs_n^{df}-algebras, generated by at least one free generator, are atomless. While the boolean reduct of the 0-generated free algebra of this class is isomorphic to the 2-elements boolean algebra. The non-atomicity of the free algebras implies (weak) Gödel incompleteness property for $GF_n^{\neq}$.

We show that the same results hold for the class consisting of the algebras in Crs_n^{df}, whose units are closed under transpositions, after extending the signature by adding the polyadic transpositions.

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Koen Lefever and **Gergely Székely**
INTERPRETATION OF SPECIAL RELATIVITY IN THE LANGUAGE OF NEWTONIAN KINEMATICS [**pdf**]

The aim of this talk is to present a new logic based understanding of the connection between special relativity and Newtonian kinematics.

We show that the axioms of special relativity can be interpreted in the language of Newtonian kinematics. This means that there is a logical translation function from the language of special relativity to the language of Newtonian kinematics which translates the axioms of special relativity into consequences of Newtonian

kinematics.

We will also show that if we distinguish a class of observers (representing the Newtonian observes stationary with respect to the "Ether") in special relativity and exclude the non-slower-than light observers from Newtonian kinematics by an extra axiom, then the two theories become definitionally equivalent (i.e., they become equivalent theories in the sense as the theory of lattices as algebraic structures is the same as the theory of lattices as partially ordered sets).

So within an axiomatic framework of mathematical logic, we explicitly show that the transition from Newtonian kinematics to special relativity is the knowledge acquisition of that there is no "Ether" and inertial observers can only move slower than the speed of light.

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Judit Madarász and **Gergely Székely**

A COMPLETENESS THEOREM FOR GENERAL RELATIVITY

We introduce several first-order axiom systems for general relativity and show that they are complete with respect to the standard models of general relativity, i.e., to Lorentzian manifolds having the corresponding smoothness properties.

This is only a sample of our approach (see the references in [2]) to the logical analysis of special and general relativity theory in the axiomatic framework of modern mathematical logic. The aim of our research is to build a flexible hierarchy of axiom systems (instead of one axiom system only), analyzing the logical connections between the different axioms and axiomatizations. We try to formulate simple, logically transparent and intuitively convincing axioms. The questions we study include: What is believed and why? - Which axioms are responsible for certain predictions? - What happens if we discard some axioms? - Can we change the axioms, and at what price?

[1] H. Andréka, J.X. Madarász, I. Németi, and G. Székely, An axiom system for general relativity complete with respect to Lorentzian manifolds, arXiv:1310.1475, 2013.
[2] H. Andréka, J.X. Madarász, I. Németi, and G. Székely, A logic road from special relativity to general relativity, Synthese, vol. 186 (2012), no. 3, pp. 633-649, arXiv:1005.0960.

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John Byron Manchak

EPISTEMIC ''HOLES'' IN SPACETIME [**pdf**]

A number of models of general relativity seem to contain ''holes'' which are thought to be ''physically unreasonable''. One seeks a condition to rule out these models. We examine a number of possibilities already on the table. We then introduce a new condition: epistemic hole-freeness. Epistemic hole-freeness is not just a new condition --- it is new in kind. In particular, its motivation is primarily epistemic rather than metaphysical.

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Attila Molnár
SOME EXPRESSIVE TEMPORAL LOGIC OF MINKOWSKI SPACETIMES [**pdf**]

A class of first-order temporal logics of Minkowski spacetimes will be presented that has the following properties:

- Strong expressive power: The language can express the basic paradigmatic relativistic effects of kinematics such as time dilation, length contraction, twin paradox, etc.
- Strong Axiomatic Base: The temporal formulas that represent the basic paradigmatic effects of relativity theories can be derived from a finite scheme axiom system SpecClockSys.
- Operationality: The coordinatization itself is definable using (metric) tense operators with signalling procedures. These operators refer to inertial agents drifting in space and conducting signalling experiments to discover the spacetime they live in. The well-definedness of that coordinatization process is also derivable from SpecClockSys.
- Completeness and Decidability: The true formulas of the acceleration-free 4D Minkowski spacetime can be derived from a finite scheme based axiom system SpecClockSysNoAcc.
- Hybrid sort definition: Nominals, i.e., a hybrid sort can be defined in (connected models of) SpecClockSys, and hybrid operators $@_i$, $\downarrow_i$ and the somewhere operator E is also definable.
- Formal comparison to other first-order axiom systems:
Those extensions of SpecRel where there are no FTL bodies and observationally indiscernible bodies are definitionally equivalent with the standard translation of some extension of SpecClockSys. This means that all classical systems with that property is equivalent to a natural temporal logic.
- Incompleteness of unrestricted acceleration in flat spacetimes: In flat Minkowski spacetimes, the existence of certain curves will result in drastic increase of expressive power which results in the interpretability of Robinson-arithmetic Q and representability of recursive functions, hence the true formulas of the 4D Minkowski spacetime with all (not necessarily inertial) timelike curves are not finite-scheme axiomatizable.

In the talk we will overview these results focusing on
- how can we find temporal logical correspondents for classical axiom systems of flat spacetimes, and
- how can we construct branching spacetimes, indeterminist spacetimes using these ideas.

Most details can be found in the preliminary phd draft of the author: **http://phil.elte.hu/attila/MA-phd-draft.pdf**

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István Németi and **Hajnal Andréka**
RELATIVITY THEORY VIA A NETWORK OF LOGIC THEORIES [**pdf**]

We investigate relativity theory (special, general, cosmological) in form of a category of first-order logic theories as objects and interpretations between them as morphisms. The common aspect in these theories is that they all concern relativity theory with

different emphasis, different details, different aspects, different formalisms, different resolutions. This is a pluralistic approach.

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Riccardo Pinosio
RELATIVISTIC SPACETIME FROM EVENTS [**pdf**]

This talk has three main aims. This first aim is to present a remarkable connection between the Kantian-Aristotelian theory of the temporal continuum, as we find it in Kant's Critique of Pure Reason and in Aristotle's Physics, and work on the construction of time and spacetime from event structures, along the lines of A.G. Walker and S. K. Thomason. The second aim is that of outlining a formalization of Kant's theory of time which we have developed on the basis of the Walker-Thomason construction; we show that the unit interval [0,1] is homeomorphic to the space of boundaries on the inverse limit of a directed diagram of event structures, defined axiomatically, and that a particular event structure obtained from [0,1] provides a universal model for the axioms. The third aim is that of relating this approach to recent work on finitary approximations of compact Hausdorff spaces, developed independently in physics and digital topology.

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Josep Pons, **Donald Salisbury** and **Kurt Sundermeyer**
THE ISSUE OF OBSERVABLES IN GENERAL RELATIVITY

For generally covariant theories like general relativity the generic dependency of observables on the original fields is derived, corresponding to coordinate-dependent gauge fixings. Clarifying some conceptual puzzles, with this approach one can make full contact with the "evolving constants of motion" program. Generic properties of observables, especially their dynamics and their Poisson algebra in terms of Dirac brackets, are also derived.

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Sarita Rosenstock, **James Weatherall** and **Thomas Barrett**
ON EINSTEIN ALGEBRAS AND RELATIVISTIC SPACETIMES [**pdf**]

We demonstrate the categorical duality of general relativity and what Geroch (1972) calls "Einstein algebras." This provides a new case study for the use of category theory to explore theoretical equivalence, as described in Barrett and Halvorson (2015). We discuss the implications of this result to Earman's (1979) claim that Einstein algebras can be used to express general relativity in a "relationist," rather than "substantivalist," manner. We argue that the categorical duality demonstrates that they cannot meaningfully be taken to be structurally distinct theories.

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Tarek Sayed Ahmed
SPLITTING METHODS IN ALGEBRAIC LOGIC [**pdf**]

We deal with various splitting methods in algebraic logic. The word 'splitting' refers to splitting some of the atoms in a given relation or cylindric algebra each into one or more subatoms obtaining a bigger algebra, where the number of subatoms obtained after splitting is adjusted for a certain combinatorial purpose. This number (of subatoms) can be an infinite cardinal. Splitting

methods existing in a scattered form in the literature, possibly under different names, proved useful in obtaining (negative) results on non--atom canonicity, non--finite axiomatizability and non--first order definability for various classes of relation and cylindric algebras. In a unified framework, we give several known and other new examples of each. Our framework covers Monk's splitting, Andréka's splitting, and, also, so--called blow up and blur constructions involving splitting (atoms) in finite Monk--like algebras and rainbow algebras. For example, for each finite n>2, we blow up and blur the finite rainbow CA_n based on n+1 greens and n reds, by splitting the red `colours' each into ω many red colours, obtaining a weakly representable atom structure **At**, whose \de\ completion (in symbols) Cm**At**\not\in **S**Nr_nCA_{n+3}. We readily infer that for any k ≥ 3, the variety **S**Nr_nCA_{n+k} is not atom--canonical obtaining the seminal result of Hodkinson's on non--atom canonicity of RCA_n as the limiting case when k=ω. Another sample: Fix a class **K** of Boolean algebras with operators. We split all atoms of a finite given atom structure having the signature of **K** each into one or more subatoms. This splitting is done *twice*, thereby obtaining two distinct atomic algebras \A and \B, such that \A\notin **K**, \B∈**K**, but \A is 'still close' to \B. We study two different notions of closeness. One is that first order formulas cannot distinguish between \A and \B, so that \A\equiv \B, hence **K** cannot be axiomatized by a set of first order sentences. Using this technique, we show that for 1< n < ω and k ≥ 5, the classes $Nr_nCA_ω$ and $RaCA_k$ are not elementary. The second notion is that m--variable equations cannot distinguish between \A and \B for a given finite m>1. From this, we deduce that, for any finite n>2, the variety **K**=RDf_n (of diagonal--free representable CA_ns) does not admit a universal axiomatization using only finitely many variables. This is done by constructing such an \A\notin RDf_n and \B∈ RDf_n for every fixed in advance finite m>1 to be finite and simple (having no proper ideals).

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Denis I. Saveliev

THE LAPSE OF TIME IN TIME LOOPS AND CYCLIC TEMPORAL LOGIC [**pdf**]

Gödel's pioneer work stating possibility of closed timelike curves posed various questions, some of which concern acceptability of such common concepts as the lapse of time. Gödel himself wrote [1]:

... in whatever way one may assume time to be lapsing, there will always exist possible observers to whose experienced lapse of time no objective lapse corresponds... But if the experience of the lapse of time can exist without an objective lapse of time, no reason can be given why an objective lapse of time should be assumed at all.

and also

... if someone asserts that this absolute time is lapsing, he accepts as a consequence that whether or not an objective lapse of time exists (i.e, whether or not a time in the ordinary sense of the word

exists) depends on the particular way in which matter and its motion are arranged in the world. This is not a straightforward contradiction; nevertheless, a philosophical view leading to such consequences can hardly be considered as satisfactory.

We argue that this conclusion is based on an implicit understanding time as ordered, and that the concept of lapsing time can be repaired by understanding time as endowed by a certain ternary relation, which turns out to be a cyclic order on time loops. A similar view may be applied to the concept of causality where a binary relation between a cause and its consequence should be replaced a ternary relation. Specifically, we propose a modal logic of cyclic time involving a binary modality and establish soundness and completeness results.

[1] Kurt Gödel, Collected Works, vol. II, III, Feferman et al. (eds.), Oxford University Press, 1995.

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Atriya Sen, **Selmer Bringsjord**, **Nick Marton** and **John Licato**
TOWARD DIAGRAMMATIC AUTOMATED DISCOVERY IN AXIOMATIC PHYSICS [**pdf**]

At the First International Conference on Logic and Relativity, Bringsjord, on behalf of a trio of RAIR- Lab researchers, showed a formal, semi-automated, symbolic proof of Theorem NEAT (No Event at Two Places). Extension and refinement of this research appeared subsequently (in Synthese). This prior work, like 99.9% of proof-oriented work in the formal sciences, is homogeneously linguistic in nature: the proofs in question are based exclusively on formal languages; diagrams, pictures, images, etc. are nowhere to be seen. Yet mathematical physicists routinely employ (informal) visual and diagrammatic reasoning in their proofs. A formal system leveraging both visual and symbolic reasoning enables heterogeneous proofs that are (i) not only more readable, intuitive, and consistent with scientific practice, but also (ii) simpler (in a formal sense), and therefore potentially easier for machines to discover on their own. Herein, we announce the availability of precisely such a system, one built directly atop Vivid, a heterogeneous logicist framework in turn built atop denotational proof languages (DPLs); and we employ the system to move closer to a formal, semi-automated proof of Theorem NEAT that is at once both linguistic and diagrammatic.

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Mike Stannett
USING AN AUTOMATED THEOREM PROVER TO SUPPORT FIRST ORDER RELATIVITY THEORY [**pdf**]

We discuss our recent attempts with Németi et al. to machine-verify proofs in first-order relativity theory using the Isabelle/HOL automated proof assistant [SN14]. We show in detail how a common background context for SpecRel/AccRel/GenRel can be defined, and how theorems in these logics can both be expressed and proven using the system. Our investigation to date has focussed on SpecRel, and suggests that the development of an Isabelle/HOL library may prove invaluable for researchers in the field. But considerable further development is required if certain, considerably more far-reaching, results in GenRel are to be

verified.

A live practical demonstration of the steps involved in using Isabelle/HOL to prove SpecRel theorems will be included.

REFERENCES
[SN14] Mike Stannett and István Németi. Using Isabelle/HOL to Verify First-Order Relativity Theory. Journal of Automated Reasoning, 52(4):361-378, 2014.

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Petr Švarný

BRANCHING CONTINUATIONS WITH OBSERVERS

We investigate a version of Branching continuations, a follow-up to Belnap's Branching space-time. This version is, however, inspired by the SpecRel system of the Németi group. We attempt to introduce physical features to the Branching framework like observers, photons, etc. The resulting system is a dynamic branching logic with a partial ability to capture common temporal conundrums, like the twin paradox, thanks to its physical part but also quantum puzzles, like the EPR paradox, thanks to its branching part. We show in both cases how the system does this and compare the results to the approaches from branching or first order theories.

Main references:
Andréka, H.; Madarász, J. X.; Németi, I.; Székely, G., 2008. Axiomatizing relativistic dynamics without conservation postulates. Studia Logica, 89(2), 163-186.
Belnap, N., 1992. Branching Space-Time. Synthese 92, 385-434.
Placek, T., 2009. Possibilities without possible worlds/histories. Journal of Philosophical Logic 1-29.
Placek, T.; Wroński, L., 2009. On Infinite EPR-like Correlations. Synthese. 167. 1-32.

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Gergely Székely

WHAT STRUCTURES CAN NUMBERS HAVE IN RELATIVITY THEORY? [**pdf**]

To have a clear understanding of the fundamental assumptions of our physical theories, we should also carefully investigate our assumptions about the structure of physical quantities.

Almost all of the physical theories assume that the structure of quantities is isomorphic to that of real numbers despite the fact that the outcomes of measurements are finite decimals (hence rational numbers). So this assumption is not at all self-evident.

Therefore, the investigation of the role of our assumptions about the structure of quantities is a natural foundational research problem.

In this talk we are going to investigate this research direction in the case of relativity theory.

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György Szondy

HOW GENERALIZED MINKOWSKI FOUR-FORCE LEADS TO SCALAR-TENSOR GRAVITY [**pdf**]

In Special Relativity minkowski four-force is known to be perpendicular to the four-velocity and four-momentum vector. In the '50s Károly Novobátzky worked out the generalization of this four-force. We will shortly explain how this formalism can be used to describe conservative fields and how it leads to a Scalar-Tensor gravity that also fits the mathematical background of GPS.

We also explain how this Scalar-Tensor gravity related to General Relativity and how can we derive the necessary scalar function (gravitation potential) from the Ricci scalar of the metric tensor. As a final thought we introduce an enhancement of a quantum particle model, where rest mass depends on backgound curvature - explaining the correspondance between gravitation potential and background curvature as revealed in the Scalar-Tensor theory above.

Poster version was presented on the 5th Central Europian Relativity Seminar (26-28th February 2015, Budapest, at Hungarian Academy of Sciences) **http://www.univie.ac.at/cers5/**
Presented on a seminar at Eötvö Lorand University (ELTE), Hungary (2015.04.29)

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János Tanács

THE UNTENABILITY OF THE STANDARD PLATONIST VIEW: A THREAT FROM THE INCOMPATIBLE MATHEMATICAL THEORIES [**pdf**]

The presentation distinguishes two types of Platonist approach, namely the Standard (or Traditional) one and the newly emerged or Full-blooded (or Robust) one. In relation to this distinction I am going to argue that if the ontology of mathematics is intended to defend plausibly in a Platonist way then this cannot be done according to the Standard version. This will draw our attention to the plausibility of the Full-Blooded version.
The plausibility of the two versions of Platonism will be examined in relation to the central problems of the philosophy of mathematics, namely the truth-proof problem and the accessibility problem. The surveying of the truth-proof problem will bring to the surface the prima facie plausibility of the Platonist approach, as well as the apparent accessibility problem of it. Focusing on the accessibility problem will help us to identify two conditions that have to be met any particular access theory of Platonism. These will be the reducibility condition, and the matching one. The Traditional version will appear an insufficient philosophical theory in relation to the two former conditions. The insufficiency will be demonstrated in the area of the incompatible mathematical theories, namely in the area of Euclidean and hyperbolic geometries. It will turn out that the Full-Blooded Platonism can escape the squeeze of these conditions, so can it save the original prima facie plausibility of the Platonist approach.

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Sándor Vályi
MONADIC SECOND-ORDER THEORIES OF THE CHRONOLOGICAL ACCESSIBILITY RELATION [**pdf**]

We investigate the monadic second-order theory of chronological accessibility relation of the n-dimensional rational spacetime (n>1). We prove that its forall-fragment is not recursively enumerable, when n>2, while in the case of n=2 this fragment is recursively enumerable however the forall-exists-fragment is not. Further, we show that the forall-fragment of the monadic second-order theory of the n-dimensional real spacetime is not recursively enumerable, for each n>1.

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James Weatherall
UNDERSTANDING GAUGE [**pdf**]

I consider two usages of the expression ''gauge theory''. On one, a gauge theory is a theory with excess structure; on the other, a gauge theory is any theory appropriately related to classical electromagnetism. I make precise one sense in which one formulation of electromagnetism, the paradigmatic gauge theory on both usages, may be understood to have excess structure, and then argue that gauge theories on the second usage, including Yang-Mills theory and general relativity, do not generally have excess structure in this sense.